CLAIMS

What is claimed is:

1. A method for scene modeling and change detection in an image, comprising the steps of:

computing optical flow for said image;

performing an invariant transformation such that image pixel intensity is transformed and evaluated in an illumination-invariant space;

forming a background model in a high-dimensional space;

utilizing results of said computing optical flow and of said invariant transformation as features in said background model;

utilizing said background model to estimate probability for a current input to belong to the background;

providing a first and a second indication whenever said probability is respectively above and below a given threshold;

adding said current input to said image background model whenever said probability is above said threshold;

adding said current input to said image background model with a low probability whenever said probability is below said threshold; and

performing morphological operations on said pixel-level detection for outputting detection.

2. A method as recited in claim 1, wherein said background model is developed in a high-dimensional space using kernel density estimation.

3. A method for dynamic scene modeling and change detection applicable to motion analysis, comprising the steps of:

making measurements of optical flow and intensities for said dynamic scene;

utilizing said optical flow measurements for capturing and modeling the dynamics of said scene;

evaluating uncertainties in said measurements; and

combining said optical flow measurements, said intensities, and said uncertainties so as to develop a robust representation of said scene in a higher dimensional space.

4. A method as recited in claim 3, wherein said step of evaluating uncertainties in said measurements comprises the steps of:

applying an optical flow constraint equation at a given point defined by a spatial location and time to obtain respective constraints;

applying an error function to combine said respective constraints from each said given point within a defined region for deriving a characteristic function;

deriving a motion estimate from said characteristic function; and

comparing said motion estimate with a given uncertainty model so as to derive a figure of uncertainty for optical flow measurement data.

5. A method as recited in claim 4, wherein said figure of uncertainty exhibits a Gaussian characteristic.

6. A method for dynamic scene modeling and change detection applicable to motion analysis, comprising the steps of:

deriving optical flow measurement data for said dynamic scene;

deriving intensity data for said dynamic scene;

deriving flow covariance matrices for said optical flow measurement data;

deriving intensity covariance matrices for said intensity data;

applying relevance criteria to said flow and said intensity covariance matrices for selecting relevant features of a subset thereof; and

combining said relevant features of said subset for performing detection.

7. A method as recited in claim 6, wherein said step of deriving intensity covariance

matrices comprises a step of deriving covariance matrices of normalized color representation.

8. A method as recited in claim 6, wherein said step of combining said relevant features comprises detection at a particular pixel.

9. A method as recited in claim 6, wherein said step of deriving optical flow measurement data comprises applying the Simoncelli algorithm.

10. method as recited in claim 6, wherein said step of deriving optical flow measurement data comprises the steps of:

applying an optical flow constraint equation at a given point defined by a spatial location and time to obtain respective constraints;

applying an error function to combine said respective constraints from each said given point within a defined region for deriving a characteristic function;

deriving a motion estimate from said characteristic function; and

comparing said motion estimate with a given uncertainty model so as to derive a figure of uncertainty for optical flow measurement data;

performing optimized detection by combining said optical flow measurement data and said intensity data;

deriving covariance matrices for said measurements;

evaluating uncertainties in said measurements; and

combining said optical flow measurements, said intensities and said uncertainties so as to develop a robust representation of said scene in a higher dimensional space.

11. A method for dynamic scene modeling and change detection applicable to motion analysis, comprising the steps of:

making measurements of intensity;

deriving measurements of optical flow for said dynamic scene;

building a probability distribution of said intensity and said optical flow in a joint 5-dimensional space comprising 3 color components and 2 flow components;

utilizing said optical flow measurements for capturing and modeling the dynamics of said scene; and

combining said optical flow measurements, said intensities and said probability distribution so as to develop a robust representation of said scene in a higher dimensional space.

12. A method in accordance with claim 11, wherein said step of building a probability distribution comprises kernel density estimation.

13. A method in accordance with claim 11, wherein said step of making measurements of optical flow for said dynamic scene comprises utilizing optical flow information to discriminate between observations exhibiting similar color components.

14. A method for dynamic scene modeling and change detection applicable to motion analysis, comprising the steps of:

inputting a current image of said scene, and previously stored frames thereof;

representing said current image in a subspace;

learning a dynamical model in said subspace;

adapting said subspace in accordance with changes in said scene;

adapting parameters of said dynamical model in accordance with changes in said scene so as to provide a prediction of said scene;

determining differences between said prediction and said current image; and

outputting an indication of a new object when said differences meet predetermined criteria.

15. A method in accordance with claim 14, wherein said step of adapting the subspace comprises updating the basis vectors thereof in an incremental manner.

16 A method in accordance with claim 14, wherein said step of adapting parameters of said dynamical model comprises updating parameters of an autoregressive model thereof in

an incremental manner.

17. A method in accordance with claim 14, wherein said step of determining differences between said prediction and said current image comprises observing structural changes in the appearance of pixel intensities in a given region.

18. A method in accordance with claim 14, wherein said step of determining differences between said prediction and said current image comprises observing changes in motion characteristics.

19. A method for dynamic scene modeling and change detection applicable to motion analysis, comprising the steps of:

inputting a current image of said scene, and previously stored frames thereof;

dividing said image into blocks, said blocks being represented as respective block vectors;

forming an auto-regressive model utilizing said current image and said previously stored frames;

projecting ones of said image blocks onto the basis vectors for obtaining the current state;

predicting a predicted current state from the previous states using said auto-regressive model;

comparing said current image with said predicted current state to determine whether said current image can be predicted by said auto-regressive model;

if said current image can be predicted by said auto-regressive model, add said current image to said auto-regressive model; and

if said current image cannot be predicted by said auto-regressive model, add said current image to said auto-regressive model with a low probability value, and output detection of a new object in said current image.

20. A method in accordance with claim 19 , wherein said step of forming an autoregressive model comprises performing principal component analysis to find principal components

21. A method in accordance with claim 19 , wherein said step of forming an auto-regressive model utilizing said current image and said previously stored frames comprises performing an incremental solution of a system of linear equations.

22. A method for dynamic scene modeling and change detection applicable to motion analysis, comprising the steps of:

making actual observations of said scene;

developing a dynamical model of said scene by utilizing multiple past frames to provide a prediction of the next frame;

updating said dynamical model by utilizing an incremental method;

making a state-driven comparison between said prediction and said actual observation; and

identifying differences in said comparison.

23. A method for dynamic scene modeling and change detection applicable to motion analysis, comprising the steps of:

inputting an image of said scene, including previously stored frames thereof;

dividing said image into blocks, said blocks being represented as respective block vectors;

performing principal component analysis (PCA) for each of said blocks using a given number of said previously stored frames so as to provide current state vector;

deriving an auto-regressive model using state vectors observed for said previously stored frames;

determining differences between said current state vector and said auto-regressive model; and

if said differences exceed a predetermined level, determining that a new object is present that is moving differently from its background.

24. A method for dynamic scene modeling and change detection applicable to motion

analysis, comprising the steps of:

inputting an image of said scene, including previously stored frames thereof;

dividing said image into blocks, said blocks being represented as respective block vectors;

forming a current state vector of values derived by forming the dot product of respective ones of said block vectors with the basis vectors;

deriving an auto-regressive model using state vectors observed for said previously stored frames;

testing whether said current state vector can be projected onto said basis vectors; and if said current state vector cannot be projected onto said basis vectors, then indicating that a new object is present that is moving differently from its background.

25. Apparatus for scene modeling and change detection in an image, comprising:

means for computing optical flow for said image;

means for performing an invariant transformation such that image pixel intensity is transformed and evaluated in an illumination-invariant space;

means for forming a background model in a high-dimensional space;

means for utilizing results of said computing optical flow and of said invariant transformation as features in said background model;

means for utilizing said background model to estimate probability for a current input to belong to the background;

means for providing a first and a second indication whenever said probability is respectively above and below a given threshold;

means for adding said current input to said image background model whenever said probability is above said threshold;

means for adding said current input to said image background model with a low probability whenever said probability is below said threshold; and

means for performing morphological operations on said pixel-level detection for outputting detection.

26. Apparatus for dynamic scene modeling and change detection applicable to motion analysis, comprises:

means for inputting an image of the scene, including previously stored frames thereof;

means for dividing the image into blocks, the blocks being represented as respective block vectors;

means for forming a current state vector of values derived by forming the dot product of respective ones of the block vectors with the basis vectors;

means for deriving an auto-regressive model using state vectors observed for the previously stored frames; and

means for testing whether the current state vector can be projected onto the basis vectors and for determining if the current state vector cannot be projected onto the basis vectors, then indicating that a new object is present that is moving differently from its background.